ORIGINAL ARTICLE

Imaging Factors Related to Rotator Cuff Tear in Patients with Deltoid Contracture

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Background: Bony deformity and muscular malfunction around the shoulder induced by deltoid contracture may influence rotator cuff function and lead to subsequent tearing. The purpose of this study was to investigate the imaging and clinical factors related to rotator cuff tear in patients with deltoid contracture.
Methods: We retrospectively reviewed 48 shoulders in 44 patients with magnetic resonance imaging diagnosis of deltoid contracture and surgically-proven rotator cuff tear. These shoulders were subdivided into partial-thickness and full-thickness tear groups. Another 17 shoulders in 17 patients with deltoid contracture but no evident rotator cuff tear were included as the control group. The characteristics, including age, gender and imaging features, of these three groups were compared.
Results: Two patients who underwent initial operations for cuff tears required secondary operations for distal release of deltoid contracture. The age of patients with full-thickness tear was significantly greater than that of patients with partial-thickness tear or without tear. The winging angle of the glenoid (WAG) in the full-thickness tear group was significantly greater than that in the partial-thickness tear group. Patients with partial-thickness tear also had greater WAG than those without tear. However, WAG was not significantly correlated with the fibrotic size or age of the patient.
Conclusion: In patients with deltoid contracture, age and WAG are associated with the development of rotator cuff tear. To prevent the occurrence of rotator cuff tear, early surgical release of deltoid contracture is highly recommended, especially in patients with greater WAG. [*J Formos Med Assoc* 2006;105(2):132–138]

Key Words: deltoid contracture, magnetic resonance imaging, rotator cuff tear

Deltoid contracture is a chronic muscular disorder that is usually induced by multiple repeated intramuscular injections and, occasionally, by congenital fibrosis or trauma.[1–8] Histopathologically, the fibrous abduction contracture is correlated to conspicuous epimysial, perimysial and endomysial fibrosis with embedding focal degenerative or regenerative changes of the muscle fibers.[9,10] Various mechanisms related to the development of deltoid contracture including chemical myositis, mechanical injury, local pressure, drug toxicity, myoischemia and entrapped neuropathy have been proposed.[10–14] Once abduction contracture develops, subsequent anatomic changes encompassing winging (lateroanterior rotation) of the scapula and subluxation of the glenohumeral joint might occur.[3,15,16] During normal arm elevation and abduction, a vertical shearing force generated by the contraction of deltoid muscle should be counterbalanced by the compressive force from the rotator cuff muscles to prevent impingement of the supraspinatus tendon between the greater tuberosity and coracoacromial arch.[17,18] Adequate coordination and counterbalance between the deltoid and rotator cuff muscles are imperative to avoid the development of subacromial impinge-

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ment syndrome and rotator cuff tear. In patients with deltoid contracture, malalignment of the scapula and glenohumeral joint, and malfunction of the deltoid muscle can alter these coordinated mechanisms. The relationships between deltoid contracture and rotator cuff tendinopathy have seldom been addressed.[3,19,20] The purpose of this study was to investigate the imaging and clinical factors related to development of rotator cuff tear in patients with deltoid contracture.

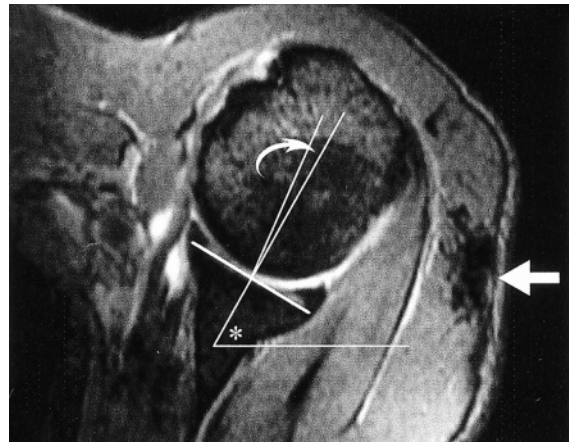

Figure. Axial gradient echo magnetic resonance image at the middle glenoid level showing an irregularly shaped hypointense mass at the middle deltoid muscle (arrow), suggestive of deltoid contracture. The winging angle of the glenoid (*), measured between the axis of the glenoid (obtained by drawing a line perpendicular to the line representing the plane of the glenoid articular surface) and coronal plane of the chest, is 64°. The glenohumeral angle (curved arrow) is 11.1°, demonstrating anterior subluxation of the humeral head.

Methods

A total of 48 shoulders in 44 patients with magnetic resonance imaging (MRI) diagnosis of deltoid contracture and surgically-proven rotator cuff tear between January 1999 and March 2003 were included in this study. MRI (Horizon, 1.5 Tesla; GE Medical Systems, Milwaukee, WI, USA) was performed with the following sequences: oblique coronal fast spin echo proton density-weighted without fat suppression and T2-weighted with fat suppression; oblique sagittal fast spin echo T2-weighted without fat suppression and proton density-weighted with fat suppression; axial gradient echo T2-weighted images. The patient was kept in a supine position with neutral positioning of the upper extremity of interest during MRI examination. The diagnosis of deltoid contracture was established by demonstrating characteristic MRI features with hypointense cords in the deltoid muscle on all pulse sequences.[15,20] According to the operative findings, patients were subdivided into partial-thickness and full-thickness tear groups. The maximal discernible fibrotic area involved in the deltoid muscle was calculated by multiplying the maximal length by the corresponding width of the hypointense lesion on axial gradient echo MRI. The winging angle of each glenoid (WAG, the angle between the coronal plane of the chest and the axis of the glenoid) was also measured at the middle glenoid level on axial MRI. The line representing the axis of the glenoid could be obtained by drawing a line perpendicular to the line representing the plane of the glenoid articular surface at the middle glenoid level (Figure). The glenohumeral angle was defined as the angle between the axis of the glenoid and the line connecting the center of the humeral head and the center of the glenoid fossa at the middle glenoid level on axial MRI (Figure). If the latter line lay anterior to the axis of the glenoid, the glenohumeral angle was assigned a positive value. Otherwise, the angle was assigned a negative value. Anterior subluxation or posterior subluxation were recorded when the angles were greater than 10° or smaller than –10°, respectively. MRI images from another 24 normal volunteers without evidence of shoulder disorders including deltoid contracture or rotator cuff tear were collected to measure the WAG in the normal population.

All patients had anteroposterior radiographs of the shoulders taken within 7–14 days of MRI examination. Based on these radiographs, the extent of superior acromial spur and the winging (lateroanterior rotation) of the scapula (decreased width of the scapula and the glenoid margin more en face) were documented.[15] The preliminary pre-MRI clinical diagnosis, operative findings and surgical methods were also recorded.

Another 17 patients with an MRI diagnosis of deltoid contracture in 17 shoulders were also included. None had subacromial impingement or pain, and no discernible rotator cuff tear was noted on MRI. These shoulders were classified as the non-tear control group.

Differences in age, size of the fibrotic area and WAG among patients with non-tear, partial-thickness tear and full-thickness tear were analyzed by the Kruskal-Wallis test. If the analysis demonstrated a significant difference between groups, pairwise multiple comparisons with the Ryan-Einot-Gabriel-Welsch F test was performed. Chi-square or Fisher's exact tests were utilized to discriminate the differences in gender, superior acromial spur, winging of the scapula and anterior or posterior subluxation of the glenohumeral joint among the non-tear, partial-thickness tear and full-thickness tear groups. Correlations between WAG and age, as well as WAG and size of the fibrotic area were evaluated by Pearson's correlation coefficient.

Results

In the rotator cuff tear group (partial-thickness and full-thickness tear), there were 28 shoulders in women and 20 shoulders in men, with an overall patient mean age of 53.5 years (range, 25–73 years) (Table 1). The left shoulder was involved in 27 (56.2%) and the right shoulder in 21 (43.8%) cases. All patients reported having received several or multiple repeated injections in the deltoid muscle except for six patients who denied or could not remember any injection history. Before the MRI study, a preliminary clinical diagnosis of deltoid contracture was made in only 12 out of 48 shoulders (25.0%).

All patients received operations for rotator cuff tears which could include open anterior acromioplasty, incision of coracoacromial ligament, bursectomy or repair of the rotator cuff depending on the condition (Table 1). For patients with MRI findings of partial tear of the rotator cuff, arthroscopic examination and debridement of the glenohumeral joint were performed to determine whether an articular side tear of the cuff tendon existed. Eighteen shoulders (37.5%) in 18 patients also received simultaneous distal release of the deltoid contracture during operation, and histologic examinations confirmed fibrotic changes in the deltoid. The other two patients (4.2%) who suffered from persistent discomfort in the shoulder after operation for rotator cuff tear required distal release for the deltoid contracture 3 and 5 months later, respectively.

MRI revealed fibrotic cords in the middle deltoid in all shoulders, while 35 shoulders (71.4% of tear group) also showed involvement of the posterior deltoid. The differences in age among the full-thickness tear (57.5 ± 8.0 years), partial-thickness tear (49.5 ± 11 years) and non-tear (50.0 ± 13.7 years) groups were significant ($p = 0.024$) (Table 2). *Post hoc* multiple comparisons indicated that the age of patients with full-thickness tear was significantly greater than those with non-tear or partial-thickness tear, but no significant difference was found between the non-tear and partial-thickness tear groups. All six patients with subluxation of the glenohumeral joint showed anterior subluxation and external rotation of the humeral head. The mean glenohumeral angle in these patients at the middle glenoid level on axial MRI was 13.4° (range, 11.1–15.3°). Four of these patients presented with involvement of the posterior deltoid muscle. Nevertheless, no posterior subluxation was found in this study. The incidences of superior acromial spur, winging of the scapula and anterior subluxation of the glenohumeral joint were 33.3%, 41.7% and 12.5%, respectively,

Table 1. Characteristics of 48 shoulders with deltoid contracture and surgically-verified rotator cuff tear

Age (yr), mean ± SD (range)	53.5 ± 10.4 (25–73)
Left/Right shoulder, *n*	27/21
Location of rotator cuff tear, *n*	
Supraspinatus tendon	48 (with 5 also involving the infraspinatus tendon)
Pre-MRI clinical diagnosis, *n*	
RCT	34
RCT and DC	11
DC and trauma	1
RCT and trauma	2
Surgical methods, *n*	
For RCT only	28
For RCT and DC simultaneously	18
For RCT first and for DC 3 or 5 months later	2

DC = deltoid contracture; MRI = magnetic resonance imaging; RCT = rotator cuff tear; SD = standard deviation.

Table 2. Age, gender and imaging findings in patients with or without rotator cuff tear

	Non-tear (n = 17)	Partial-thickness tear (n = 24)	Full-thickness tear (n = 24)	p
Age (yr), mean ± SD (range)	50.0 ± 13.7 (25–77)	49.5 ± 11.0 (25–73)	57.5 ± 8.0 (40–73)	0.024*
Gender (female/male), n	8/9	15/9	13/11	0.783†
Superior acromial spur (+/–), n	4/13	6/18	10/14	0.345†
Winging of the scapula (+/–), n	7/10	11/13	9/15	0.842†
Anterior subluxation of glenohumeral joint (+/–), n	0/17	4/20	2/22	0.189†
Size of fibrotic area (cm^2), mean ± SD (range)	2.4 ± 1.5 (0.7–5.3)	2.1 ± 1.4 (0.5–6.0)	2.0 ± 1.0 (0.6–4.8)	0.749*
WAG (°), mean ± SD (range)	46.0 ± 6.1 (35.0–62.1)	51.0 ± 7.7 (39.8–67.2)	56.5 ± 7.5 (44.6–74.8)	< 0.001*
Correlation	Non- and partial-thickness tear	Non- and full-thickness tear	Partial- and full-thickness tear	
WAG and age, p	0.331‡	0.175‡	0.744‡	
WAG and fibrotic size, p	0.148‡	0.637‡	0.208‡	

**Kruskal-Wallis test; †chi-square or Fisher's exact test; ‡Pearson's correlation coefficient. +/– = positive/negative; SD = standard deviation; WAG = winging angle of the glenoid.*

in all 48 shoulders of the tear group. There were no significant differences in gender, superior acromial spur, winging of the scapula or subluxation of the glenohumeral joint among patients in the non-tear, partial-thickness tear and full-thickness tear groups.

The mean size of the fibrotic areas in the 48 shoulders of the tear group was 2.0 ± 1.2 cm^2. No significant differences were found in the size of the fibrotic area among the non-tear (2.4 ± 1.5 cm^2), partial-thickness tear (2.1 ± 1.4 cm^2) and full-thickness tear (2.0 ± 1.0 cm^2) groups (p = 0.753). However, the mean size of the fibrotic area in the six patients with anterior subluxation of the glenohumeral joint was 3.7 cm^2 (range, 2.6–6.0 cm^2). The mean ± standard deviation of the WAG measured at the middle glenoid level on axial MRI was 43.4 ± 4.3° (range, 34.2–51.7°) in 24 normal volunteers (age, 22–68 years), 53.8 ± 8.0° in the tear group and 46.0 ± 6.1° in the non-tear group. The differences in WAG among patients in the non-tear, partial-thickness tear (51.0 ± 7.7°) and full-thickness tear (56.5 ± 7.5°) groups were significant ($p < 0.001$). Further *post hoc* multiple comparisons confirmed that patients with full-thickness tear had significantly greater WAG than those with partial-thickness tear, and patients with partial-thickness tear also had significantly greater WAG than those without tear. No significant correlations were found between WAG and age, or between WAG and the size of the fibrotic area in the non-tear, partial-thickness tear and full-thickness tear groups.

Discussion

Deltoid contracture is a chronic muscular disorder which usually presents as abnormal abduction of the arm due to muscular fibrosis. In the vast majority of patients, fibrosis of the deltoid is induced by multiple repeated intramuscular injections.[1–8] Occasionally, deltoid contracture may be congenital or post-traumatic. Repeated intramuscular injections may trigger chemical myositis, mechanical injury, local pressure, drug toxicity, myoischemia and entrapped neuropathy, and subsequently lead to fibrosis of the muscle.[10–14] Once fibrosis develops, coalition of the adjoining perimysial and epimysial tissues occurs and ultimately evolves into contracture status.[9,10] In our country, intramuscular injection is a common practice in local clinics for the management of patients with fever, pain or infection. The deltoid, gluteal and quadriceps muscles are the most common sites for these injections.[3,9,10,15] The deltoid muscle is composed of anterior, middle and posterior portions. The anterior and posterior fibers descend obliquely without interruption into the tendon. Nevertheless, the middle portion is characterized by a multipennate structure with prominent connective tissue, which is distinctly different from the anterior and posterior portions.[1,21,22] The unique nature of this structure and its status as the preferred site for intramuscular injection by clinical practitioners predispose the middle deltoid muscle to the development of deltoid contracture.[1,3,20]

Clinically, deltoid contracture is characterized by pain around the neck and shoulder, dimpling of the skin at the contracture site, palpable fibrous cord, winging of the scapula and limited adduction of the upper arm.[3,15] Distinctively radiographic manifestations including lateral down-sloping of the acromion, superior acromial spur, and lateroanterior or lateroinferior rotation of the scapula can be detected on conventional radiographs.[3,15,16] However, for patients with mild clinical symptoms and for those without bony deformity, the subclinical existence of deltoid contracture may be overlooked. Preliminary pre-MRI clinical diagnosis of deltoid contracture with rotator cuff tear was made in only 25% in this series. Therefore, a significant proportion of deltoid contracture was overlooked when there were concomitant shoulder disorders such as rotator cuff tear. In this study, two patients required a secondary operation for deltoid contracture to relieve shoulder discomfort and deformity 3 and 5 months after the initial operation for rotator cuff tear. Ko et al reported results of distal release of deltoid contracture in 40 patients, three of whom received secondary operations of anterior acromioplasty and repair of rotator cuff tear 12–14 months later.[3] Therefore, in patients with coexistence of rotator cuff tear and deltoid contracture, meticulous evaluation before surgical intervention is mandatory to improve planning and reduce the likelihood that a secondary operation will be needed. MRI provides an opportunity for early diagnosis of deltoid contracture by disclosing intramuscular fibrous cords in the deltoid as hypointense lesions on all pulse sequences.[15,20] MRI might be warranted to diagnose the coexistence of rotator cuff tear and deltoid contracture.

The aging process of cuff tendons has been reported to be independent of chronologic old age, and histologically-identifiable degenerative changes can occur as early as the third decade of life.[23,24] Nonetheless, a significant association between the age of the patient and the occurrence of rotator cuff tear has been reported.[24] In a cadaver study, Yamanaka and Fukuda reported that 89% of cases with age-related changes in the supraspinatus tendons were over 50 years of age.[25] This study demonstrated that, in patients with deltoid contracture, the age of patients with full-thickness tear of the cuff tendon were significantly older than those with partial-thickness tear or without tear (Table 2). This suggests that aging is a major predisposing factor to rotator cuff tear in patients with deltoid contracture. Early surgical intervention to release the contracture might prevent the aggravation of rotator cuff tear.

The primary functions of the deltoid muscle are elevation and abduction of the upper arm. The deltoid, especially the middle portion, is the largest contributor to elevation of the arm and generates a vertical shearing force that should be counterbalanced by a compressive force from the rotator cuff muscles to effect precise motions and prevent subacromial impingement.[17,18,26] Malfunction of the deltoid muscle due to deltoid contracture may alter the biomechanics of arm elevation and abduction. Without the coordination of the deltoid and rotator cuff muscles, subacromial impingement and subsequent rotator cuff tear may occur during arm elevation or abduction. In this study, the WAG was the only anatomic change found on imaging study that could worsen the status of rotator cuff tear. Patients with partial-thickness tear had significantly greater WAG than those without tear. Furthermore, significantly greater WAG was found in patients with full-thickness tear than in those with partial-thickness tear. Good coordination of the glenohumeral joint and gliding of the scapula is necessary for normal elevation and abduction of the upper arm.[17,24,27] An abnormally greater WAG in patients with deltoid contracture may limit the scapulohumeral rhythm. Hence, during arm elevation and abduction, the clearance of the greater tuberosity from the undersurface of the coracoacromial arch may be hindered. Under these circumstances, aggravation of subacromial impingement with subsequent rotator cuff tear may occur.

Chen et al reported that the winging angle of the scapula in patients with deltoid contracture was significantly greater than that in the normal population and was moderately correlated with the diameter of fibrotic cord in the deltoid.[15] In this study, the great diversity in the shape of the scapular glenoid and body actually increased the difficulty in measuring the axis of the scapula. The glenohumeral joint plays a major role in shoulder disorders. We also measured the axis of the glenoid in this study to emphasize the crucial role of the glenohumeral joint in patients with deltoid contracture. The mean WAG (53.7 ± 8.0°) in patients in the tear group was greater than that in the non-tear group (46.0 ± 6.1°) and normal population (43.4 ± 4.3°). The range of the WAG in the non-tear group was 39.9–52.1°. A WAG greater than 52° was found in 60.4% of patients in the tear group and only 17.6% of patients in the non-tear group (chi-square test, $p = 0.004$). Therefore, a WAG of greater than 52° could be considered to be a predisposing factor for rotator cuff tear in patients with deltoid contracture. Whether restoration of the WAG occurs after surgical release of the deltoid contracture remains unclear. Ko et al reported that distal release of the deltoid contracture could correct the range of motion at the shoulder in patients with deltoid contracture, including abduction-contracture, extension-contracture and horizontal-abduction angles in 86–100% of cases.[3] Surgical intervention could improve the scapulothoracic rhythm and expedite the clearance of the greater tuberosity from the undersurface of the coracoacromial arch to hinder the occurrence of subacromial impingement and subsequent tear of the rotator cuff. To prevent the occurrence of rotator cuff tear, early surgical release of the deltoid contracture to restore the scapulothoracic rhythm is highly recommended, especially in patients with greater WAG.

This study found no significant correlation between WAG and size of the fibrotic area, or between WAG and patient age. Therefore, increased WAG in patients with deltoid contracture seems to be an independent predisposing factor to worsen tendinopathy of the rotator cuff, which was unrelated to age or fibrotic size. In patients with deltoid contracture, the fibrotic contracture in the deltoid could lead to clinical presentation of various degrees of abduction-contracture of the arm and/or anterior rotation of the scapula. Anterior rotation of the scapula results in a widened WAG. We propose that there is a balance between the abduction-contracture of the arm and anterior rotation of the scapula. For those patients with more prominent anterior rotation of the scapulohumeral complex, greater widening of the WAG will occur. Nevertheless, patients who develop less severe anterior rotation of the scapulohumeral complex might exhibit a more apparent abduction-contracture posture and less widening of the WAG. The differences might explain why large fibrotic size did not correlate with the widened WAG in this study.

In this series, four out of the six patients with anterior subluxation of the glenohumeral joint showed involvement of both the middle and posterior deltoid muscles. The mean fibrotic size in patients with anterior subluxation was greater than that in patients without anterior subluxation. Therefore, the size of the fibrotic area and the site of the contracture band may contribute to the development of anterior subluxation of the shoulder joint in deltoid contracture. Further study involving a greater number of cases is needed to confirm this hypothesis.

In summary, the clinical presentation of deltoid contracture may be masked when patients have concomitant disorders, such as rotator cuff lesions, leading to under-diagnosis. MRI is a useful diagnostic tool to detect the coexistence of deltoid contracture and rotator cuff tear, and allows better planning for surgical intervention. In patients with deltoid contracture, age and WAG are predisposing factors that may result in or aggravate rotator cuff tear. To prevent the occurrence of rotator cuff tear, early surgical release of deltoid contracture is highly recommended, especially in patients with greater WAG.

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